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To: Mr. F.J. Kee
Director of Research

**FIBER-OPTIC ATTENUATION TESTS
FAIRCHILD TS x LESLIE TS - FINAL REPORT**

R.C. Madge

The attenuation of a fiber-optic communication system between Fairchild TS and Leslie TS was monitored at intervals from February, 1985 to August, 1985. Variations in signal strength were minimal through a 47°C temperature range. Some temperature sensitivity was observed. A concurrent vibration study showed no correlation between skywire vibration and optical attenuation. No relationship was seen between optical fiber attenuation and wind or precipitation conditions.

INTRODUCTION

A cable with 4 optical fibers was lashed to one of the skywires of the Fairchild TS x Leslie TS 230-kV circuits C18R/C20R. A patch cord was installed between Fibres 1 and 3 at Fairchild TS to create a 10.4 km loop. An optical signal source, attenuation monitor and printer were housed at Leslie TS and attenuation readings were printed out every 10 minutes from February 14, 1985 to May 26, 1985, and from July 31, 1985 to August 7, 1985. Canstar Communications generously loaned this equipment to us for these tests. Appendix A describes the components in detail.

Weather reports were obtained of the hourly temperature, wind speed and direction and precipitation values at the Pearson International Airport in Toronto. In addition, a study of the effects of the optical fiber cable on skywire vibrations was carried out by Transmission Operations from January 14 to March 24, 1985. The data were made available to us for correlation with optical attenuation data.

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740618-360-423	816.6	March 14, 1986	86-50-K

The optical fiber communication system exhibited no observable settling time on power-up or re-hookup conditions and did not seem to be adversely affected by repeated power on/off's.

CALIBRATION

Figure No.'s A1 and A2 of the Appendix show the measurement setup. Calibration of the system, as shown in Figure No. A1, involved connecting the optical transmitter directly to the receiver. The digital output of the monitor was +3.11 dB. This value was stable and repeatable with subsequent reconnections. The noise floor of the monitor, in the absence of any signal, was -39 dB. This gave us a very comfortable dynamic range of over 42 dB.

To ensure that the source was not varying with time and temperature the calibration process was repeated roughly every week for the duration of the tests. Micro-adjustments could be made to the monitor to re-establish a +3.11 dB reading. This was never found to be necessary as the source level did not seem to vary.

Following each recalibration the system was again set up as in Figure No. A2 of the Appendix. Unfortunately, the repeatability of the transmitter pigtail-to-optical cable connection was very poor. Variations in attenuation of over 6 dB could be achieved by rotation of the fibers with respect to each other. Extreme care was taken after each recalibration to ensure that the original orientation was reestablished. However, this orientation was found to introduce 4 dB of attenuation more than the optimal amount. As this was not discovered until two weeks into the tests, it was decided to continue unchanged rather than optimize the connection and lose the valuable cold weather data.

ABSOLUTE ATTENUATION LOSS

From the manufacturer's field worksheet/2/, 5.2 km single-direction attenuation losses of 29.6 dB for each fiber could be expected. However previous tests performed on these fibers/2/ showed the single-direction losses were much smaller:

Fibre No 1	- 15.5 dB
Fibre No 2	- 19.1 dB
Fibre No 3	- 17.0 dB
Fibre No 4	- 22.1 dB

Since Fiber No.'s 1 and 3 were connected to form the present 10.4 km loop we should expect about 32.5 dB fiber loss plus patch cord and connector losses. Figure No. 1 shows the attenuation losses to actually be 37.8 to 38.2 dB. As mentioned in the Calibration section above, the initial orientation of the fibers resulted in 4 dB of attenuation above the optimal amount. This would reduce the overall loss to 33.8 to 34.2 dB. Patch cord and connector losses

could easily account for the 1.3 to 1.7 dB difference.

TEMPERATURE EFFECTS

Weather data at the Pearson International Airport was made available every hour, on the hour, 24 hours a day. Straight-line interpolation was used to correlate the temperature readings with the attenuation values printed out every 10 minutes. Figure No. 1 shows the optical fiber loop attenuation versus temperature curve for the complete test. A minimum of 10 attenuation values in each 1°C range were required to be a valid point on the curve.

Note that the curve shows a slight temperature sensitivity response. The attenuation scale has been expanded considerably to show this response. A minimum attenuation of 37.8 dB was found for temperatures from 8 to 20°C. The maximum attenuation is only slightly higher, however, at 38.2 dB for -13°C. The spike at 29°C can be taken to be a statistical anomaly. Overall the curve is quite stable.

The interim report of this project/1/ dealt with data collected from February 14, 1985 to May 26, 1985 only. It showed a curve quite similar to Figure No. 1. However, there was a sharp increase in response starting at 28°C. It was not known at the time whether this was anomalous or indicated the bottom end of a severe temperature response. Figure No. 2 shows this early curve with a curve representing the July 31, 1985 to August 7, 1985 data. It can be seen that the later data does not support a sharp attenuation dropoff with temperature.

Figure No. 3 shows a month-by-month break down of the attenuation vs temperature data. There is a drift in the data that should not be there. Note the largest differences during the early cold months. Possible explanations include:

- a) A slow temporal drift in the performance of the equipment could result in the first two months showing the largest differences. By the third month the equipment had settled down. This effect should have been corrected by the periodic recalibration of the source and monitor.
- b) The temperature response deals with the outside temperature affecting the optical fiber cable. However, the equipment inside the building is affected by the building temperature. It can be assumed that the building was coldest for February and gradually warmed up through the spring. Therefore, the different curves could be showing the temperature response of the equipment and not the optical fiber cable. This effect should have been corrected by the periodic recalibration of the source and monitor.

- c) Snow and ice loading on the skywire with the optical fiber cable could have increased the length of the cable. Some additional attenuation could be the result. Vibration analysis of the skywires, however, shows little to no excessive loading, vibration or displacement. Therefore, there should be no additional attenuation for these reasons.
- d) Human error could exist in the initial calibration and subsequent recalibrations, reconnections of the transmitter pigtail to the optical fiber cable, and analysis of the data. The data, however, clearly shows consistent differences. One would expect that human error would result in more random variations in the attenuation vs temperature curves.

It should be kept in mind that the overall spread in attenuation is very small over a broad range of temperatures. This variation is quite acceptable and represents only a 0.4 dB total, or 0.04 dB/km variation over 47°C.

WIND AND PRECIPITATION EFFECTS

Weather data from the airport included hourly wind speed and direction and 6 hourly precipitation values. The airport is located roughly 25 kilometres to the west of Leslie TS. The wind speed could have an effect on the shape and tension of the overhead ground wires and thereby affect the optical fiber performance. However this effect would be highly dependent on the wind direction.

Cursory analysis showed that wind speed and direction varied considerably through each day and seemed to have no discernible effect on the attenuation loss. Also the wind speed and direction could be considerably different in the built-up suburban area of Scarborough surrounding Leslie TS than at the airport. Because of this no analysis was performed on the effects of wind on attenuation.

The six-hour precipitation values were often unavailable leaving 12 or 18 hour gaps in the data. As expected, there appeared to be no correlation between precipitation and attenuation, and no analysis was performed.

VIBRATION EFFECTS

Transmission Operations performed vibration studies of the effects of the optical fiber cable on the skywires from January 14 to March 24, 1985/3/. They placed recording equipment on both the skywire with the optical fiber cable and the skywire without it. These tests overlapped the optical attenuation tests for a short time.

No excessive vibrational amplitudes or frequencies were recorded on

either skywire. The skywire with the optical cable exhibited slightly higher levels. The maximum peak/peak skywire bending amplitude measured during the testing was 3 mils. This is well within the maximum allowable limit of 5.5 mils.

Because the measured vibrations were considered acceptable, and exhibited consistent values for each two-week period of the test, there was no need to correlate attenuation levels with vibration measurements.

CONCLUSIONS

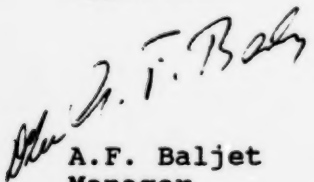
Despite a temperature range of 47°C the optical attenuation of the system remained steady at 38.0 $\pm$ 0.2 dB. There was some temperature sensitivity in this 0.4 dB spread. A breakdown of attenuation versus temperature by month showed initial differences in the attenuation response during the first two months. Various explanations were discussed without a satisfactory one being found. The variation is so small, however, as to be considered harmless.

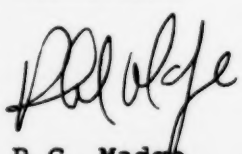
Although wind speed, wind direction, precipitation and vibration data were available there seemed to be no discernible relationship with optical attenuation.

Vibrational amplitudes and frequencies of the skywires were recorded and found to be well within allowable limits.

Approved:

Submitted:

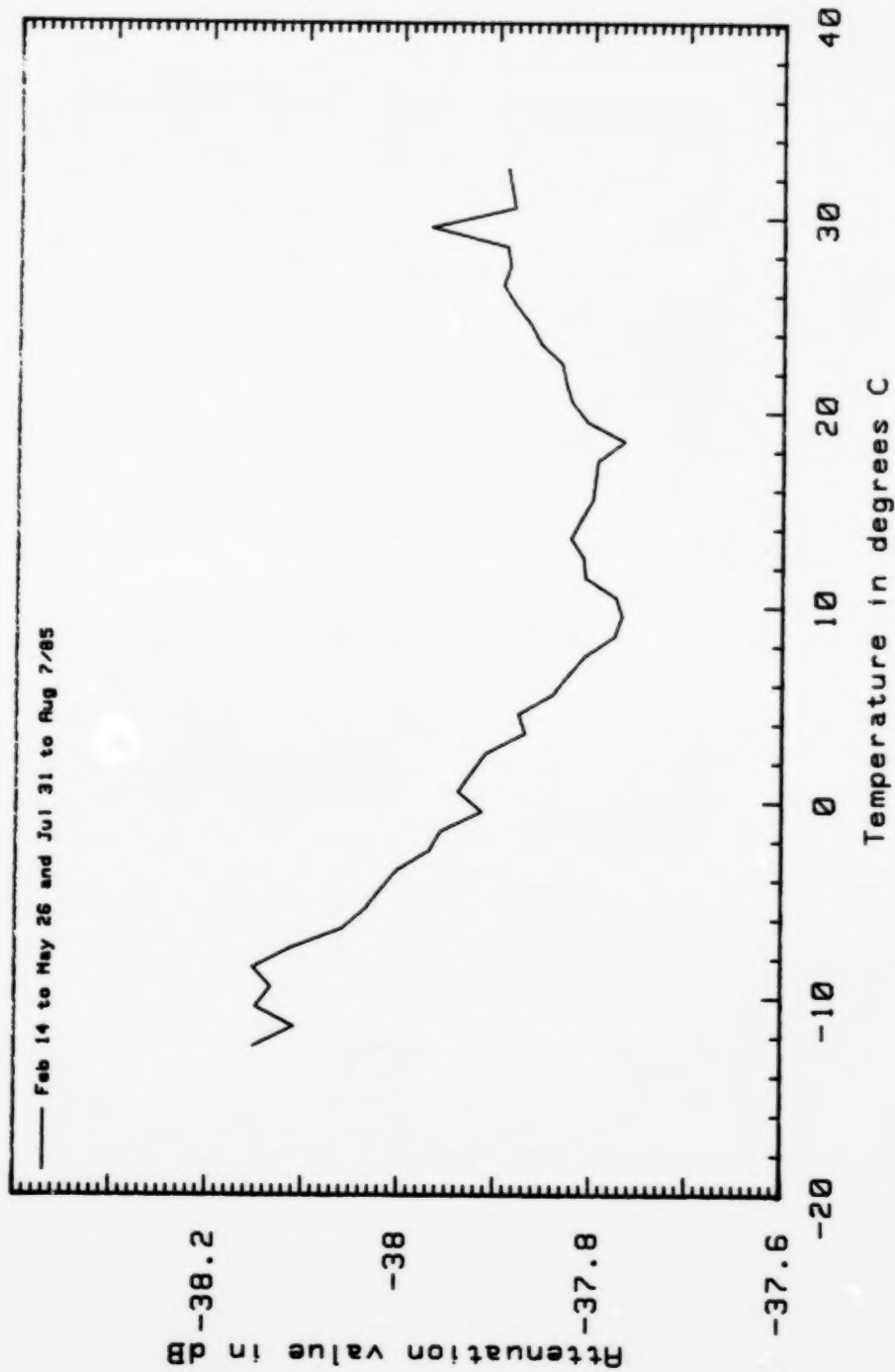

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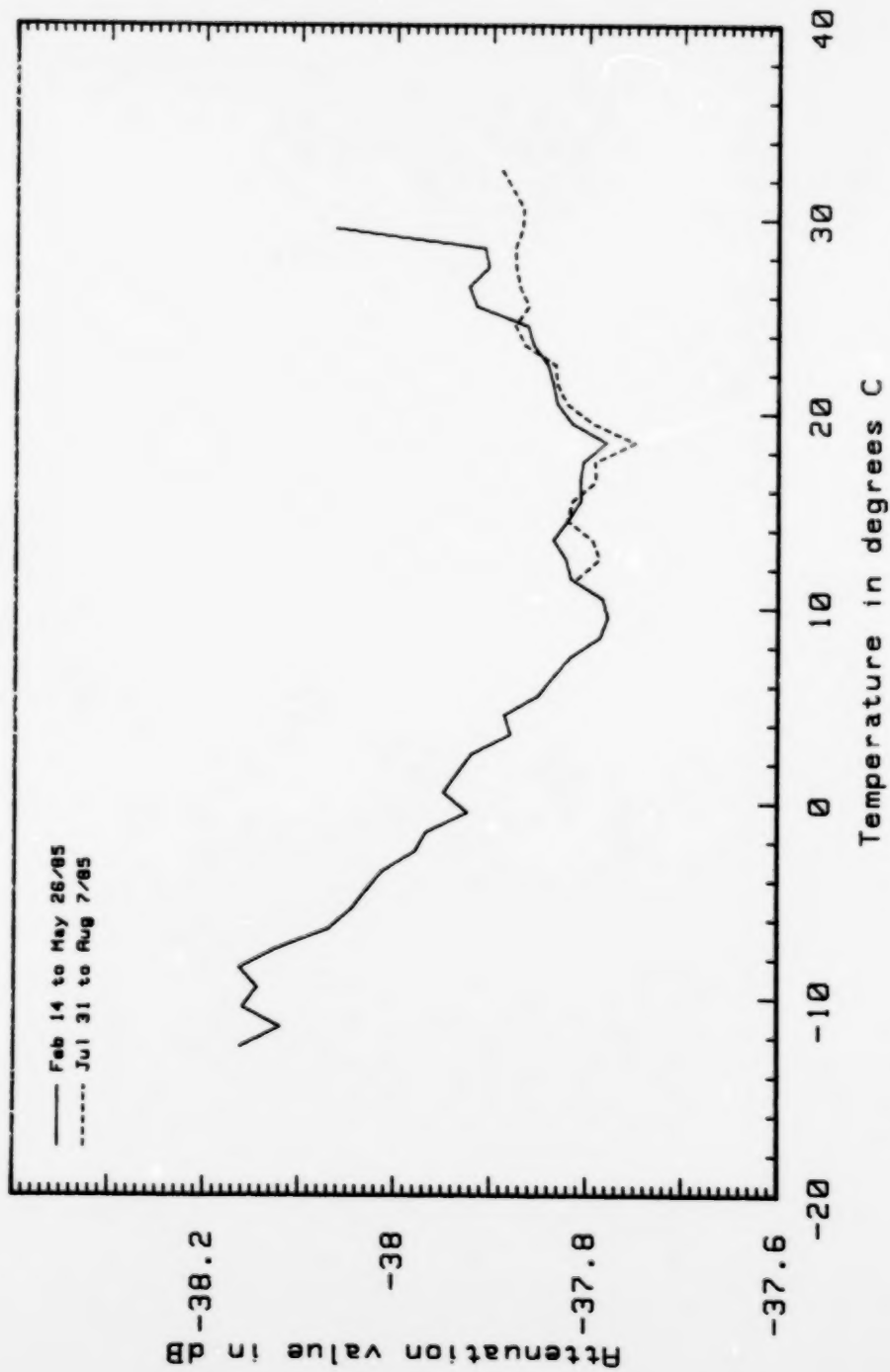
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1. Madge, R.C., Fibre-Optic Link Attenuation Monitoring - Fairchild TS x Leslie TS. July 19, 1985, 85-225-K.
2. Jones, D.E., Fibre Optics Communication System Using Digital Techniques - Progress Report. November 6, 1984, 84-372-K.
3. Carreira, A.J., Memorandum to D.E. Amm. "Vibration Study on the Shieldwires of Circuits C18R/C20R to Accommodate Fiber Optic Cable System". File #TOD 435.07, February 6, 1986.



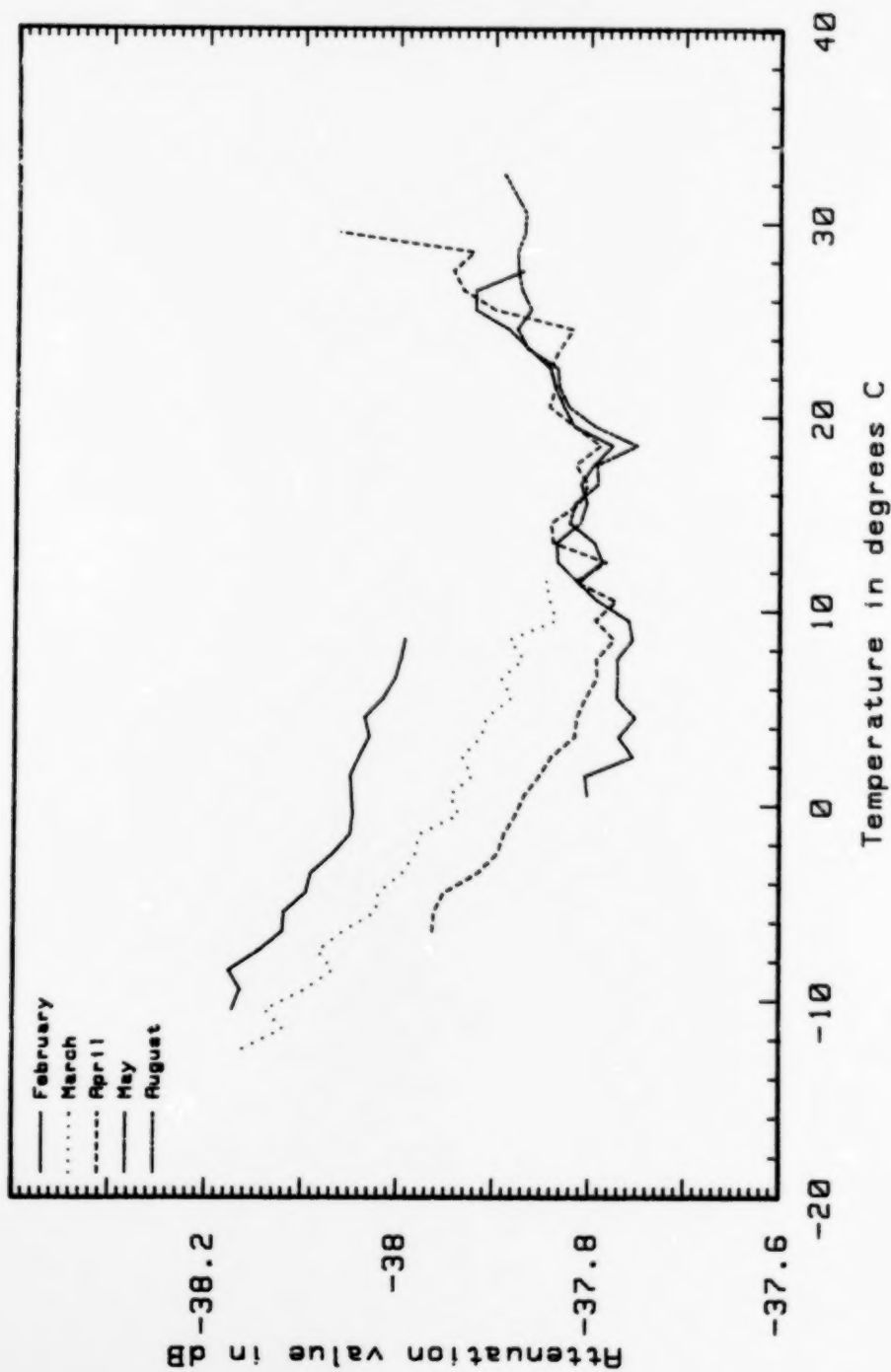
FIBRE-OPTIC LINK - FAIRCHILD TS x LESLIE TS
Attenuation vs Temperature

Figure #1.



FIBRE-OPTIC LINK - FAIRCHILD TS x LESLIE TS
Attenuation vs Temperature

Figure #2.



FIBRE-OPTIC LINK - FAIRCHILD TS x LESLIE TS
Attenuation vs Temperature

Figure #3.

APPENDIX A

The following equipment was used to measure the attenuation of the fiber-optic system.

OPTICAL TRANSMITTER: CANSTAR AAM-003TX, Serial #1717

Output Wavelength:	850 nm $\pm$ 35 nm
Output Average Power:	-30 dBm into 50/125 μ m, graded index, 0.2 NA fiber pigtail
Temperature Range:	0 to 40°C.

OPTICAL RECEIVER: CANSTAR AAM-003RX, Serial #1716

Detector Type:	Silicon PIN Diode
Optimal Wavelength:	850 nm
Input Fiber:	50/125 μ m, graded index, 0.2 NA
Measurement Accuracy:	$\pm$ 0.21 dB
Display:	4 digit LCD, 0.01 dB resolution
Temperature Range:	0 to 40°C.

PRINTER: HP 5150A, Serial #2004A04718

Data Format	Parallel BCD
Output:	10 characters on thermal sensitive paper periodic time printout periodic data printout
Temperature Range:	0 to 50°C.

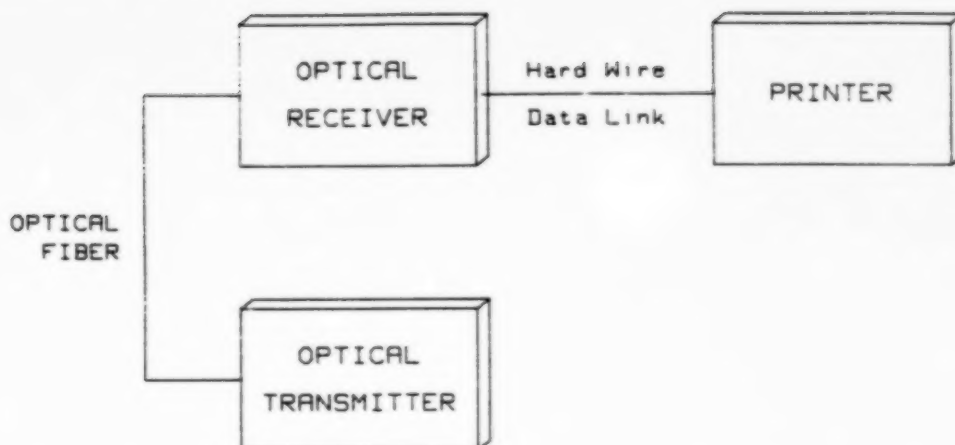


FIGURE #A1. Calibration Setup for Optical Fiber Communication System.

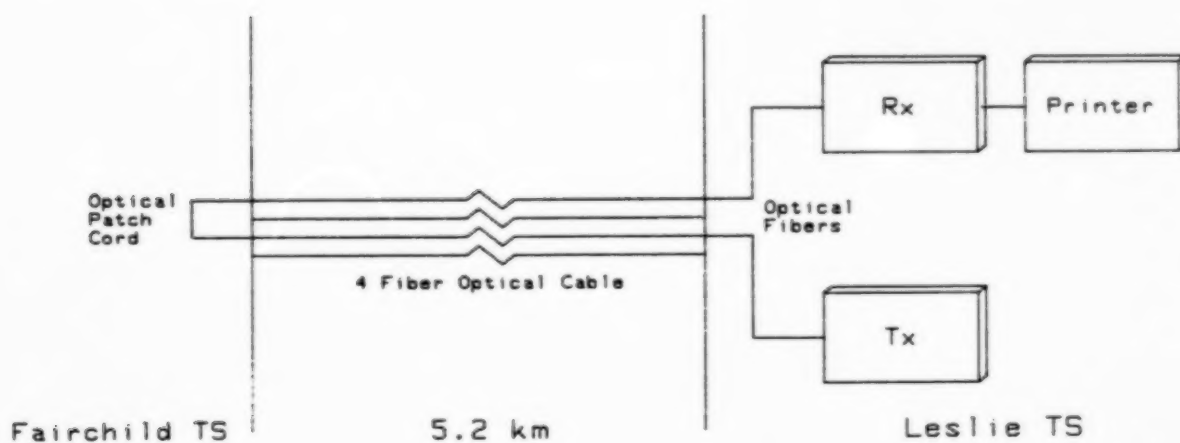


FIGURE #A2. Measurement Setup for Optical Fiber Communication System.